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IV

GEOLOGY OF THE NORTHERN END OF THE TAMPICO EMBAYMENT AREA

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INTRODUCTION

The attention of the writer was first directed to the eastern coast of Mexico as an oil field in 1890, during which year Mr. Josiah Owen, then of Eagle Pass, Texas, and later an associate for many years in coal and oil investigations for the Southern Pacific Company, made a reconnaissance trip through the region between Tampico and Tuxpam, and sent samples of heavy oil and asphalt for examination, together with a general statement as to the oil conditions, which he considered highly favorable.

In 1899 the matter was brought to the attention of Mr. C. P. Huntington as well worth investigation by the Southern Pacific Company, but it was thought at that time to be too far removed from other interests of the Company.

In 1908 the subject was again placed before the management, and an examination was ordered. Prof. W. F. Cummins, who was well acquainted with the geology of the coastal oil fields of

Texas, and who had had a year's experience in connection with artesian water investigations in northeastern Mexico, was placed in charge of the work, which began with an effort to connect the known geological section of the Texas side of the Rio Grande with the formations of the Mexican oil fields. The results of this work, as given in a paper entitled "Tertiary Deposits of Northeastern Mexico"[1] show that the Gulf Coast Tertiary deposits which carry the Texas oil are not represented in the Tampico-Tuxpam oil fields, but that the oil formations there are a continuation of the Cretaceous.[2]

During the years which have followed, the geologists of the Southern Pacific Company have continued work in this area under the direction of the writer and much information has been accumulated regarding the stratigraphy and some good collections of fossils have been made, the most of which were placed in the hands of Dr. R. E. Dickerson, Curator, Department of Invertebrate Paleontology, California Academy of Sciences, for identification.

It is proposed in this paper to give briefly the results of our work and, based on Dr. Dickerson's and Dr. W. S. W. Kew's determinations of the fossils, to show as nearly as possible the ages of the formations encountered. Descriptions of the collections have been made by Dickerson and Kew in a separate paper[3].

The Area

The region under consideration is a narrow belt of country on the eastern coast of Mexico, beginning just north of the twentieth parallel and extending to the twenty-fourth. From Nautla to Tampico it comprises the entire coastal strip lying between the Cordilleras, or Sierra Madre Oriental, and the waters of the Gulf of Mexico. North of Tampico it is bounded on the west by the Cordilleras and on the east by the Tamaulipas range, thus forming the valley through which runs the railway between Tampico and Monterey.

This area is the northern portion of what has been called the Tampico Embayment.[4] It is economically important because

[1] Proc. Cal. Acad. Sci., 4th Series, Vol. V, No. 6.
[2] Dumble, "The Occurrences of Petroleum in Eastern Mexico as Contrasted with those in Texas and Louisiana." Trans. A. I. M. E. August, 1915.
[3] A Medial Tertiary Fauna from Northeastern Mexico. Proc. Cal. Acad. Sci. 1917, Vol. VII, No. 5.
[4] Some Events in the Eogene History of the Present Coastal Plain of the Gulf of Mexico in Texas and Mexico. Journal of Geology, Vol. XXIII, No. 6, p. 481 et seq.

of the vast quantity of petroleum that has been developed in it during recent years. It is geologically important not only on account of the oil, but also because it furnishes the key to certain heretofore unsolved problems regarding the relationship of adjacent land areas to continental growth.

This area, some 300 miles in length, will not average 50 miles in width. Its greatest breadth, which is less than 100 miles, is found along the course of the Panuco River and its tributaries, whence it narrows both to the north and to the south.

Physiography

Topographically, the area as a whole is a plain sloping gently gulfward. Along its western border are low ranges and ridges, rarely exceeding 300 meters in height, caused by the strong folding and faulting of the Cretaceous rocks together with some of those of earlier Tertiary age which form its basement. To the east of these its undulating surface is broken by hills of erosion and by peaks of intrusive basaltic rocks. North of the Panuco River these interruptions are less numerous than they are to the southward. The most prominent remnantal elevations are found in a series of peaks, mesas and ranges beginning at Chicontepec and stretching northeastward to the Otontopec range which ends near Tantima. This forms the divide between the drainage of the Panuco and that of the Tuxpam River.

Between these two rivers are two intermediate coastal basins which have been carved out and are drained by the Cucharas and the Tancochin and a like service is performed by the Cazones and Tecolutla for the area between Tuxpam and Nautla.

The principal drainage system north of the Panuco is the Soto la Marina and between it and the Conchos River, along which we found exposures of typical Gulf Coast Tertiaries, lie the mountain masses of the Sierra de San Carlos and the Sierra Cruillas of the Tamaulipas range. These mountains extend westward to within 15 miles of the railroad south of Linares, greatly narrowing the valley at that point.

Much of the surface is covered by the dense vegetable growth of the semi-tropics and for the most part the so-called

roads are only trails. Good exposures of the rock materials are, therefore, scarce except along drainage channels and certain hillsides, making it difficult to trace the continuations of any of the formations over any considerable area. If we add to this the fact that fossiliferous horizons are comparatively few and frequently discontinuous, the difficulty of accurate correlation of the beds of separated areas will be readily apparent. It is for this reason, doubtless, that some confusion has arisen.

Publications

The publications bearing directly on the geology of this area are not very numerous.

Among the earlier papers relating to the eastern coast of Mexico, those by Deshayes, Heilprin and Sapper give only the results of their observations on the Pliocene of Yucatan.

The first definite statement regarding the geology of this particular district is that of Böse in his itinerary of the trip from San Luis Potosi to Tampico, published in the Guide Book for the excursions of the International Congress of Geologists in 1906.

Böse regards that part of the massive limestones with rudistes near Tamasopa and Micos, and which is last seen between El Abra and Taninul, as Meso-Cretaceous and equivalent to the Cenomanian or Vraconian. These include the limestones now called Tamasopa. The shales and marls with limestone bands which overlie these and are well exposed between Valles and El Abra he classes as Neo-Cretaceous, although no fossils were found in them. The yellow to gray argillaceous shales in the plain east of Taninul he says probably belong to the Tertiary, although he found no fossils, and states that they resemble the Pliocene of Tuxpam and Papantla.

This was followed and added to by Villarello in his Report on the Oil Regions of Mexico[5], which gives clear and satisfactory descriptions of the various geological formations of the region, although later discoveries may necessitate a different reference as to the age of some of the deposits there described.

Villarello refers the massive grayish limestones along the front of the Sierra Madre Oriental to the Meso-Cretaceous,

[5] Bull. 26, Inst. Geol. Mex. 1908.

and the overlying shales and sandstones, which extend from near Victoria to the zone embraced between Valles and Taninul, to the Neo-Cretaceous. He describes these beds in the vicinity of Valles as shales, marls and occasional slates with intercalated limestones and sandstones with calcareous cement and says they are unconformable with the massive limestone. With these he also includes the interbedded limestones and sandstones occurring south and southwest of Tantoyuca.

The yellow nummulitic rocks of the San Jose de las Rusias range he refers to the Eogene, but considers all of the yellow argillaceous shales, marls, and calcareous beds south of the Tamaulipas range as Neogene and equivalent to the beds at Tuxpam and Papantla. He suggests the name Papantla for these beds. He includes in these Neogene beds the argillaceous shales east of Las Palmas and Tamuin which form the greater part of the Mendez of Jeffreys.

The Neogene to the south of the Panuco River, as described by Villarello, comprises yellowish fossiliferous calcareous rocks, such as are found outcropping in the neighborhood of Papantla, Coazintla and elsewhere, overlain by sandstones, bluish gray shales and slaty marls and reddish clays. These Neogene deposits rest upon interbedded limestones and sandstones similar to those near Tantoyuca and are overlain in places by Quaternary sediments.

These Neogene beds are broken and in places overlain by basaltic rocks and tuffs.

In 1910 Engerrand and Urbina of the Mexican Geological Commission made a preliminary survey of the Yucatan peninsula. They record Miocene fossils from Tizimin*, but regard all others as Pliocene or Pleistocene.

Böse, in Bulletin 20 of the Mexican Geological Commission, reports on the geology of Chiapas and Tabasco. No Cretaceous was observed later than the rudistes limestone (Tamasopa?). Extensive deposits of shales, clays, sandstones and limestones were found carrying a fauna composed almost altogether of nummulites and orbitoides. These he refers to the Eocene. Overlying them, he finds a series of dark shales, clays, and limestones which he describes under the name of the Semijovel division. He states that this division may embrace beds of both Oligocene and Miocene age, but that the greater part

* Bul. Mex. Geol. Soc., Vol. VI., p. 119.

of the fossils appear to belong to the Miocene. Near Macuspana and elsewhere in Tabasco he found beds containing fossils which he referred to the Marine-Pliocene.

Engerrand describes the fossils from Zuluzum near Palenque in Chiapas, which he regards as Miocene.

The beds occurring on the Isthmus of Tehuantepec (outside a small exposure of the rudistes limestone) carry an abundant fauna, but the specimens are not well preserved. The determinations of species by Dall, Toula, Böse and others and their conclusions as to age, while appearing to agree on the Pliocene or later age of these deposits, seem to indicate that a portion of them may be older than this reference. This is apparently sustained by Böse[6], who found similar beds at Santa Maria Tatetla, northwest of Veracruz, from which he described a number of species as Pliocene but later states that since larger and more careful collections have been made he considers the age to be Miocene.

It will, therefore, be seen that while Eogene fossils were recognized north of the Tamaulipas range in the district of San Jose de las Rusias, and both Eogene and Neogene sediments found south of the Isthmus of Tehuantepec, nowhere within the area of the Tampico Embayment were Tertiary deposits observed which were referred to horizons earlier than the Miocene.

This was the condition when the oil geologists began operations.

In Science of February 10, 1911, Dumble, reporting on the results of two years' work in Northeastern Mexico, reports the discovery of Oligocene deposits at San Fernando on the Conchos River and in the San Jose de las Rusias region and suggests the probable Cretaceous age of the blue shales underlying the San Fernando beds of the Oligocene in the Panuco district, which in turn were succeeded by later beds as seen at Tuxpam.

In 1910 Jeffreys made a report on the geology of eastern Mexico which, while it may not have been published, has been the basis of much that has been written by others. In this report he takes the same view of the age of the deposits in this area as that stated above.

[6] Bull. 22, Mex. Geol. Comm.

He describes the lower members of his Cretaceous under the names of Tamasopa and San Felipe, corresponding closely to the Tamasopa and San Juan of our classification. To the Mendez he refers the entire series of blue shales succeeding the San Felipe and extending eastward to and beyond Mendez. He gives these a thickness of 3000 to 3500 feet. In his section, which is reproduced by various authors, he shows the Mendez shales involved in the folding of the other Cretaceous rocks between Valles and San Felipe and states that the San Felipe beds grade upward into the Mendez and downward into the Tamasopa.

The base of the Mendez of Jeffreys is the equivalent of our Papagallos, but the top is probably Tertiary.

To the Tertiary he refers the fossiliferous beds around Tanlajas on the extreme western border of the area, the beds around Ozuluama, which he considers practically their time equivalent, and the overlying Temapache series.

In Science for June 7, 1912, Dumble reported the discovery of Eocene fossils at Alazan, northwest of Tuxpam, and gave further details of the occurrence of the San Fernando and Tuxpam beds (Miocene?) in this region.

Garfias, in his article on The Oil Regions of Northeastern Mexico[7], reviews the descriptions of the various formations as given by different geologists, adds his own observations of the region, and gives in tabular form a tentative correlation which embodies the facts brought out after Jeffreys's report by the finding of Eocene fossils at Alazan. This shows the Mendez shales as originally described, including shales of both Upper Cretaceous and Eocene age.

De Golyer[8] uses the names Tamasopa, San Felipe and Mendez for the formations found in the Furbero field, but refers both his San Felipe and Mendez to the Eocene, because of the fossils found at Alazan. He also claims an unconformity between his San Felipe and the beds he considers Cretaceous.

Huntley[9] also uses the same names for the same formations, but regards the entire Mendez of Jeffreys as Eocene.

[7] Economic Geology, Vol. X, p. 195.
[8] Trans. A. I. M. E., LII, pp. 266 et seq.
[9] Trans. A. I. M. E., LII, pp. 275 et seq.

I. C. White[10] quotes the opinion of Dr. C. W. Hayes, suggesting a Laramie age for the San Felipe and Valles beds.

A number of the geologists who have worked in this area and collected valuable data have been unable to publish it because of the character of their engagements. The writer thankfully acknowledges the assistance through co-operation and criticism of a number of these gentlemen.

General Features

At first appearance the geology of this area does not seem at all complicated, but some misunderstanding and confusion have arisen from the fact that through the entire area the predominating material entering into and forming the floor of this Tampico embayment is blue shale. At its northern end the shale was proved to be Cretaceous by its position and as it was unfossiliferous and little physical change was observed, this interpretation was applied to cover all similar shales found south of these. But, it transpires that in addition to these Cretaceous blue shales there are also blue shales of Eocene and Oligocene age and these predominate south of the Tamesi River.

The eastern face of the great plateau is composed of limestones of Meso-Cretaceous age and the Rudistes limestones of Micos canyon are found as far south as Chiapas. The disturbed area at the foot and immediately in front of the main mass shows the Meso-Cretaceous limestones folded, faulted, and overlain by later beds which are also folded. From the San Juan Hills in Coahuila to Aquismon in San Luis Potosi these overlying beds appear to belong to the upper or Neo-Cretaceous.

The beds found overlying the Meso-Cretaceous of the hill country south of Aquismon have few of the characteristics of the Neo-Cretaceous of the region northward and represent such different conditions of sedimentation and fauna as to make such a reference of them impossible. Fossils are scarce in these beds but in the deposits overlying the Meso-Cretaceous in Chiapas Böse found orbitoides and nummulites that were clearly of Eocene age and similar forms occur south of Aquismon. It is, therefore, probable that in the hill country be-

[10] Bull. Geol. Soc. Am., Vol. 24, p. 253.

tween Aquismon and Chiapas, the greater part of the San Juan and Papagallos which constitute the Neo-Cretaceous of the northern basin are either overlapped or replaced by these Eocene-Tertiary beds, outcrops of which extend eastward almost to the margin of the Gulf.

The Coastal Slope lying east of this disturbed or foothill zone is largely occupied by deposits of Oligocene age as far north as the Tamaulipas Mountains and these Oligocene deposits extend along the eastern face of this range as far as the Conchos River. The only other sedimentary deposits noted are deposits of the Quaternary and Recent which are not very extensive.

Basalts and other rocks of igneous origin occur as intrusive peaks, dikes, and flows.

Cretaceous

The Mexican geologists have divided the Cretaceous, of which they have a very complete section, into Eo-Cretaceous, Meso-Cretaceous and Neo-Cretaceous in place of the two divisions, Lower Cretaceous and Upper Cretaceous, recognized in the United States.

The Meso-Cretaceous of the Mexican authors includes the upper portion of our Lower Cretaceous and the lower portion of our Upper Cretaceous.

It will appear from a comparison of the fossils that the line between our Lower and Upper Cretaceous—that is, between the Vola or Buda limestone and the Woodbine or Dakota sands —would be represented in the Meso-Cretaceous by a line drawn below the Tamasopa limestone.

While, therefore, the heavy limestones below the Tamasopa may be properly correlated with our Comanche, it would not seem allowable to include the Tamasopa in such reference.

MESO-CRETACEOUS

The Meso-Cretaceous limestones of the Tamasopa gorge, as described by Böse[11], are considered by him to represent the Cenomanian, Turonian, and possibly the Vraconian, but the Tamasopa limestone of the various reports on this region, as

[11] Guide Book Geological Congress. XXX, p. 10.

generally used, is restricted to the beds of the portion of the section which are characterized by the presence of rudistes. These are typically seen in Micos canyon and at the Choy grotto which also illustrates the cavernous condition so prevalent in this limestone.

The Tamasopa limestone is rather fine-grained, compact, creamy to gray in color, and most usually massive. It is often crystalline in structure and in places it is dolomitic.

Between the Tamesi and the Tuxpam rivers the Tamasopa limestone appears to be the principal oil producing formation, while south of the Tuxpam valley it has not been found in any of the producing wells drilled up to this time.

Villarello, describing the beds of the Meso-Cretaceous lying north of the railroad line between Tampico and San Luis Potosi, says:

"The Meso-Cretaceous is made up of limestones of a grayish color in heavy beds with a strike about 18 deg. northeast and dip of 31 deg. to the northwest. These limestones are strongly folded and faulted and constitute a great portion of the Sierra Madre Oriental which extends from the Tula district passing through the western portion of the southern and central districts of the State of Tamaulipas and afterwards enters the State of Neuvo Leon.

"The Tanchipa range rises to the west of Ebano and . . . . . is made up of limestones and shales of Meso-Cretaceous and Neo-Cretaceous age. These beds extend toward the south and are exposed in nearly the whole of the petroliferous region of Aquismon."

Of the continuation of these deposits south of the railroad he says:

"The older sedimentary rocks (of the Aquismon region) are heavy beds of a grayish colored limestone, fossiliferous in some portions, especially in the neighborhood of Choy grotto . . . . .

"These limestones constitute the Meso-Cretaceous of the region, and only the limestones in the vicinity of Xilitla probably belong to the Eo-Cretaceous.

"The Meso-Cretaceous outcrops at the following places, from the northwest of Xilitla through Tampachal and Pubuche in the Temapache Mountains, to the west of Tocomon, Aquis-

mon, and Micos and in the Colmena or Abra de Cabelleros mountains. To the east of these outcroppings and to the east of Valles the Meso-Cretaceous outcrops from the Rancho Nuevo and fraction of the Pujal on the Tampaon River to Abra and Las Palmas stations on the Mexican Central Railroad and from there extends to Tanchipa Mountains. In this range the Meso-Cretaceous limestones are covered in various places by shales and marls of Neo-Cretaceous age which come in between Valles and Abra . . . . .

"The Meso-Cretaceous . . . . . is highly folded forming anticlines and synclines sometimes very close and in general unsymmetrical."

Jeffreys describes a section in the San Dieguito Range in this region as showing at the base four feet of a dolomitized limestone with minute particles of petroleum, overlain by three feet of gray crystalline limestone which had a distinct petroliferous odor, while the overlying bed of about one foot thickness is a dark gray to almost black limestone well saturated with oil. The limestone is more or less fossiliferous throughout, hippurites and various lamellibranchs seeming to predominate.

Similar impregnations are found in heavily bedded and folded Tamasopa limestone on the eastern slopes of the Temapache mountains.

The Tamasopa limestone has been subjected to heavy folding which has formed anticlines and synclines sometimes very close and, in general, unsymmetrical, and strikes vary from 30 to 60 deg. N. of E. in the region along the railway.

Except the statement that the Meso-Cretaceous limestone forms the main body of the Sierra Madre toward the south, there is almost nothing said about it in the region between Aquismon and Orizaba.

Cummins, in his work between the Panuco and Tuxpam rivers, did not get far enough west to reach the Tamasopa limestone and saw no exposures of limestones similar to the San Juan. The most westerly exposures he observed were of materials which he believed to be Tertiary.

De Golyer, in writing of the Tamasopa south of Tuxpam, says that the main mass of the outcrop is in the Sierra Madres, the front range of which passes 28 miles west and 16 miles south of the Furbero field. The Tamasopa limestone has not been reached in any well yet drilled in this field.

He says that it "consists of hard gray, pure, compact porcelain-like limestone bedded in layers less than a foot thick and is characterized in its upper part by the occurrence of an abundance of black to dark gray and green chert nodules interbedded with the limestone . . . . . The uppermost member of the limestones which are massively bedded in the northern Veracruz and Valles region are somewhat porous and contain great solution caverns."

From this I understand that he considers the uppermost member, or Rudistes limestone of the Tamasopa, missing in this region, in which case these beds may be related to the Maltrata limestone of Böse's Orizaba section.

The Orizaba limestone (Meso-Cretaceous) of Böse consists of two divisions: The Maltrata or lower member and Escamela or upper. He describes them as follows:

"The Maltrata limestones constitute an important division, which is often of great thickness. The greater part is composed of limestones in thin beds, is without fossils, and of a clear dark gray or black color. The limestones contain numerous segregations of flint in the form of lenses. In the upper portion the flint occurs in the form of nodules and irregular bodies. In the lower part of the limestones there occur in many places intercalated argillaceous slates which are yellowish and lustrous like silk, but these never form heavy beds. In the upper part toward the boundary with the Escamela limestones, there occur gray limestones and dolomites in heavy beds in which the stratification is scarcely recognizable. Above these follow dark compact limestones which represent the passage to the Escamela limestones and which may better be considered a part of the latter. In some places there occur above the dolomites flinty limestones, and in that case the line between them and the Escamela limestone is sufficiently well marked.

"The Escamela limestones are composed of a clear gray to a dark gray limestone, in some places but slightly stratified and elsewhere in clearly distinct beds. Cherts occur only in the lower portion. There are no intercalations of slates or marls. The limestones resemble in their characters very often the Cretaceous limestones of southern Italy. They are petrographically very uniform and may be recognized with ease."

Still farther south in Chiapas he describes the Meso-Cretaceous beds thus:

"This division is much the most important in Chiapas . . . . . It consists of limestones and dolomites which generally occur in quite thick beds and only occasionally as intercalated lenses. Occasionally beds of limestone of brecciated structure are found. In the lower part there sometimes occur beds of limestone with chert concretions, but the upper part consists generally only of gray limestone with interbedded dolomite. It may be said that these strata everywhere contain rudistes, especially radiolites."

He adds that he himself has never observed beds in this vicinity which might with certainty be assigned to the Neo-Cretaceous.

NEO-CRETACEOUS

The upper members of the Cretaceous section (Neo-Cretaceous series of Mexican authors) as determined by Cummins from their occurrence in Northeastern Mexico[12] comprise a series of thin to medium-bedded limestones, with inocerami and ammonites, called by him the San Juan limestones, overlain conformably by a great thickness of dark shales, without fossils, called the Papagallos.

The San Juan Hills are made up of a series of thin to heavy-bedded limestones interstratified with thin beds of yellowish clay. Toward the base the limestones are shaly, dark gray in color and weather gray to whitish. Toward the summit the limestones are of bluish shade, weathering white. The uppermost beds are sandy and weather to a reddish or rusty brown color. They carry numerous impressions of ammonites, oysters and inocerami which are of forms referable to the Taylor or Austin Chalk.

The Papagallos consists of a series of very fine-grained blue or black limy clay shales, leaching brown, yellow or white. At their northern end, the type locality, and for some distance south, they carry both selenite and barite and break up into slaty particles. When broken down and fully weathered, they form a black clay which when wet makes a very stiff mud like the black waxy soils of central Texas.

The Cretaceous age of the San Juan was fully proved by its fossils and that the Papagallos shales, at the type locality, were also of Cretaceous age was evidenced by the fact that

[12] Tertiary Deposits of Northeastern Mexico, pp. 170 to 174.

while they were conformable with the San Juan they had been folded and eroded prior to the deposition of the succeeding sands and limestones of the basal Eocene. This is shown on the Salinas River at Ramones where there is a bed of sandstone lying in discordant stratification directly upon the crumpled and folded Papagallos shales. In this sandstone were found:

Venericardia alticostata
V. planicosta
Ostrea pulaskensis
Cucullæa macrodonta

These fossils are characteristic of the Midway, the lowest stage of the Gulf Tertiaries. There can, therefore, be no question as to the Cretaceous age of the Papagallos shales at the type locality.

Similar limestones and shales were found at San Felipe and Valles, west of Tampico, but here they were without fossils. Jeffreys called the former the San Felipe beds and applied the term Mendez to the overlying shale and its upward continuation east of the Sierra del Abra. With the idea that these were the continuations of the San Juan and Papagallos, Cummins traced the beds from the Papagallos Hills to Mendez and Valles.

It is about 10 miles from the Papagallos Hills where both San Juan and Papagallos formations occur, to San Juan on the railroad between Tampico and Monterey. Over that distance the shales are exposed in all the ravines and are the surface rocks except where covered by superficial drift. On the south side of the San Juan River, south of the town of San Juan, there is a fine exposure of the beds in a railroad cut. From San Juan to Montemorelos is 26 miles. The shales are seen at numerous places between these points, and only at such places as are drift-covered was the shale not seen. East of Montemorelos there are hills that are composed entirely of the shales. A trip of 9 miles was made west of the town toward the Sierra Madres, and after getting out of the river valley the road was continuously on the shales. Between Montemorelos and Linares, a distance of 32 miles, outcrops of the shales are numerous and they are also shown in

the floor of the valley for 25 miles southeast of Linares to the foothills of the San Carlos Mountains, in the elevation of which the San Juan is again brought up.

The San Carlos and Cruillas mountains, lying between the Conchos and Sota la Marina rivers, are composed of heavy-bedded, compact limestones (Tamasopa ?) overlain by thinner bedded fossiliferous limestones of the San Juan series followed by the Papagallos shale. On the northern or Conchos River face of the mountains the Cretaceous is overlain by the sandstones and clays of the Fayette substage of the Eocene which are last seen on the Choreras arroyo east of Cruillas; the Fayette is overlain in places by the San Rafael. On the southern face of the mountains the Sota la Marina drainage, on the contrary, shows the yellow sandy clays of the San Rafael directly overlying the Papagallos or earlier members of the Cretaceous.

Between Linares and Cruz the Papagallos shales were found exposed at Summit, Carrizo, and other points, and simillar exposures are found in the valley for 25 miles eastward. At Cruz they are exposed in the bed of Purificacion River and in the same river northwestward to Hidalgo, just west of which are hills composed of the San Juan limestone. The valley between these hills and the Sierra Madres shows the upturned edges of the shales which are finally cut out by the scarp of Tamasopa limestone. Between Cruz and Victoria the surface is largely covered with drift or Reynosa, but these surface deposits are cut through in many places and the underlying hardened blue shales can be seen dipping at a strong angle to the west. These shales were also seen just south of Victoria and in numerous gulches between Victoria and San Francisco. At San Francisco there is a well 90 feet deep in these shales and they are exposed at many different places between San Francisco and Gonzales where a well 1,500 feet deep was in the shale its entire depth. To the east of the railroad similar shales were found at Los Esteros and Mendez.

From this it will be seen that the valley between the Sierra Madre on the west and the Tamaulipas Mountains on the east from San Juan to Gonzales and Los Esteros is underlain throughout by a body of blue shales.

At Mendez a well was drilled which passed through a thousand feet of shale before entering the platy limestone of

the San Juan. From Mendez the shales were traced westward around the south end of El Abra Hills to Micos and San Dieguito, where they hold the same relation to the Tamasopa limestone that they do west of Cruz. They lie against the upturned edges of the limestone and extend to considerable heights above the valley.

The section along the railroad between Micos and Las Palmas is typical, showing the Tamasopa, San Juan, and Papagallos in their usual relations but disturbed and faulted, and a kilometre west of Las Palmas the Papagallos shales come in sight resting against the massive Tamasopa limestone with its rudistes fossils.

There can, therefore, be little doubt that the beds between the scarp of Tamasopa limestone at Micos and the El Abra Hills are the direct continuation of the San Juan and Papagallos of the north. East of El Abra Hills, however, later beds may also be present.

Böse says of this locality:

"On leaving San Mateo the road turns again to the east to descend to the large plateau of Valles. This plateau, covered by small hills, represents a broken up scale of Neo-Cretaceous shales. . . . . Above Valles the structure becomes very simple. The Neo-Cretaceous beds are slightly inclined toward the east and between Valles and El Abra the shales rest almost horizontally upon the Rudistes limestone."

From the San Juan Mountains in Coahuila to the railroad line at Valles is nearly 400 miles, and throughout this entire distance, along the face of the Sierra Madres the San Juan and Papagallos formations preserve their lithological characteristics and their general relations to the Tamasopa limestone. Numerous exposures in the valley between the Sierra Madres and the Tamaulipas range show materials apparently identical with the Papagallos, and both San Juan and Papagallos (and probably Tamasopa) occur east of the valley in the San Carlos Mountains. Wells drilled at Ebano, Topila, and Panuco also prove that the same relations continue along the floor of the valley in that vicinity, as platy limestones entirely similar to the San Juan are found overlying the Tamasopa and underlying the blue shale.

At the greater number of places where shales were observed north of the railroad they have a considerable dip to the north or west. The principal exceptions to this are certain hills lying around Victoria and Cruz, which, while composed of similar materials, are horizontally bedded. This apparent discordance of stratification may indicate that these hills are not Papagallos but outliers of the Eocene sedimentation occurring south of the Panuco River.

No fossils have been reported from the Papagallos shales but they are thought to contain foraminiferal remains and should have microscopic study.

In the Aquismon region south of the railroad line Villarello classes all of the materials lying between the Tamasopa and Quaternary as Neo-Cretaceous, which classification would include both San Juan and Papagallos, and says of them:

"Unconformably upon the Meso-Cretaceous lie shales and marls and sometimes slates between which are interpolated limestones and sandstones cemented with calcareous material. All these beds belong to the Neo-Cretaceous and . . . . . outcrop over a great extent of country.

"The Neo-Cretaceous outcrops on the north of Xilitla from the Huichihuayan Hacienda through the Tierras Coloradas, Tocamon, Huihuitlan, Tampamolon, Tancanhuitz, Aquismon and Tanquin to Valles. It extends on the west as far as the base of the Temapache and Colmena mountains and eastward as far as the Tanchipa or Boca del Abra mountains.

"The Neo-Cretaceous shales have a strike varying from North 25° E. to N.E. with dips of 10 to 20° to the west of northwest. These shales are slightly folded and sometimes form cross folds, the arches of which are little raised and of very gentle slope.

"At Huihuitlan and Tierras Coloradas sheets of coal 5 cm. thick are found interpolated with the beds of sands and shales."

While some of the deposits of the Aquismon district are Neo-Cretaceous, they cannot all be so referred. Jeffreys refers the beds east of Aquismon, which he described as his Tanalajas formation, to the upper Tertiary on the evidence

of the fossils, and states that they lie in front of the Tamasopa limestone outcrop here and to the south. He makes no mention either of Valles or Mendez in this area.

Huntley's map shows the Tanlajas beds as upper Tertiary and separated from the Tamasopa limestones lying west of them by belts of Mendez and San Felipe deposits as far southward as the map extends.

Jeffreys says his San Felipe beds are transition beds between the underlying Tamasopa limestone and the overlying Mendez shales. Limestones predominate toward the base giving place to blue shales toward the top. He estimates their thickness at not more than 500 feet. It is the equivalent of our San Juan.

Huntley describes his San Felipe formation as follows:

"This may be described as a transition series between the upper Mendez marls and shales and the underlying massive Tamasopa limestone. It begins with an occasional thin limestone shell. These increase with depth in number and thickness, being interbedded with blue shales which conversely decrease in thickness downward until the series gives place to massive limestone. These beds apparently vary in thickness from about 300 to as much as 800 feet."

It corresponds approximately to our San Juan, and on his map is confined to the eastern face of the Boca del Abra Mountains, the valley west of them, and a belt along the face of the main range.

The Mendez of Jeffreys, named from the Mendez east of Ebano, and which includes the Papagallos and probably some part of the Tertiary, is thus described:

"This formation consists of a very uniform deposit of gray to blue shales, which, in the higher levels, verge into an indurated clay or semi-marl, with a bolder fracture instead of the fine shaly appearance . . . . . From top to bottom of this Mendez marl there is practically no change in the lithological character, save some irregular beds, varying from two inches to two feet thick, of a sandy limestone."

The Mendez of Huntley is the same as that of Jeffreys, but he refers it as a whole to the Eocene. He says of it:

"The Mendez marls consist of a very uniform deposit of gray to blue shales and marls. In regions of steep folding these often show bold jointing near the surface. There is practically no change in their lithological character from top to bottom. . . . . They average from 2,000 and 3,500 feet in thickness. A few irregular beds of sandy limestone are reported in this formation, but they are not persistent."

So far as can be judged from the reports now available, south of these exposures between Micos and Valles, beds having the characteristics of the San Juan formation have only been observed as narrow detached bodies lying along the border of the Sierra Madres.

In a great many places through the region south of the railroad blue shales are found underlying the yellow clays, sands, and limestones of the Oligocene, and prior to the discovery of Tertiary fossils in such a shale at Alazan, this entire series of blue shales was supposed by us to be a continuation of those of the valley to the north and to be of similar age to the Papagallos.

The only blue shales which were originally thought to be later were found by Cummins in the region about Chicontepec and while no fossils were found, on account of the lithologic similarity of the interbedded limestones and sandstones to those on the Salinas River, these beds were tentatively referred to the Eocene.

While there is a similarity of color existing between the Alazan and Chicontepec beds on the one side and the Papagallos on the other, they differ both in composition and in weathering.

The Papagallos is prevailingly clayey, weathering first into slaty particles and finally to very black sticky soil, while the others are usually more sandy, are frequently micaceous, and often weather to grayish or yellow sandy soils or loams. The prevailing dips of the Papagallos are northward and westward and in places at rather steep angles, while the Tertiary usually dips eastward at lower angles.

South of Aquismon the scarp of Tamasopa limestone bends sharply eastward nearly to the Tempoal River, a distance of over 40 miles. It there bends southeastward again. The

continuous body of Neo-Cretaceous deposits have certainly been traced into this Aquismon Bay, and, so far as our present information goes, have not been certainly recognized in the valley south of the scarp which forms its southern boundary, except in remnantal areas.

They have been observed in a narrow outcrop stretching southeastward from Tamazunchale and in scattered areas as far south as Tecualontepec on the upper part of the Rio Espinal-Tecolutla. To the south of this they seem to have been entirely eroded.

Since the Papagallos of Aquismon Bay is identical with that farther north and shows no indication of approach to shore conditions, nor any reason to look for its immediate discontinuance, the sudden change in character of the materials southward, the Tertiary fossils of the Tanlajas beds and the finding of Eocene fossils at Alazan and of fossils of supposedly Eocene age in the underlying beds at Sabanita, gives support to the idea that a large portion, if not all, of the shales south of Aquismon belong to the Eocene, and are, therefore, of later age than the Papagallos and that the Papagallos, if it formerly extended over this area, as it most probably did, was eroded or is now covered by the beds we have called Chicontepec.

The Alazan shales are definitely proved by their fossils to be of Eocene age and are also known from similar fossils found in a well at Topila on the Panuco River. They are apparently unconformable on the underlying blue shales. Just how far these Alazan shales extend northward and what portion of the beds on the Panuco River belongs to the Papagallos and what to the Alazan or other Tertiary horizon, is unknown.

Prof. Cummins found what seemed to be the Papagallos type of shales exposed at a few localities north of the Tuxpam River, but, until better information and criteria for identification are at hand, it will be safer to treat the unfossiliferous beds of shales, clays, and sandstones, with occasional beds of limestone, which, in the region south of Panuco River, occur between the Tamasopa or San Juan and the Oligocene, as undifferentiated Chicontepec, which is referred to the Eocene.

AGE OF THE CRETACEOUS

The Tamasopa, San Juan, and Papagallos seemingly represent a long period of practically continuous sedimentation as the Tamasopa grades upward into the San Juan and the San Juan into the Papagallos, with no evidence whatever of unconformability.

While the exact contact between the Papagallos shales and the Escondido beds was not seen, the relations of the two formations in the valley of the Salado River east of the San Juan Mountains warrant the statement that the Papagallos underlies the Escondido, which is the uppermost stage of the Cretaceous of Texas.

According to Böse[13] the upper portion of the Meso-Cretaceous, here represented by the Tamasopa is of Cenomanian age and he correlates it on the basis of its paleontology with the Lower Cross Timber or Woodbine sands of the Texas region. The few fossils found in the San Juan prove it to be the equivalent of the Austin or Taylor and the Papagallos underlies the Escondido. It would, therefore, seem fairly well determined that the Tamasopa, San Juan, and Papagallos are the time equivalents of the Upper Cretaceous of the Texas section from the Woodbine to the Taylor, inclusive, and that so far no uppermost Cretaceous corresponding to the Escondido or Webberville has been observed south of the Tamaulipas barrier.

Tertiary

EOCENE

The Eocene deposits of the Tampico Embayment area are quite different from those of the region north of the Tamaulipas range. In the latter the beds are very fossiliferous and both lithologically and faunally are identical with the various subdivisions of the Lower and Middle Eocene which have been recognized in Texas.

While the Chicontepec beds somewhat resemble the beds of the Lower Eocene of Texas lithologically, no fossils have yet been found corresponding to those of the Midway, Wilcox, or Lower Claiborne. The principal forms occurring in them

[13] Neue Beiträge zur Kentniss der Mex. Kreide.

are nummulites and orbitoides, with a few undetermined mollusks.

In the northern portion of the area, west of the Tamaulipas Range, no beds were found which, because of their fossils, could be positively referred to the Tertiary. However, certain sandy shales were seen along the railroad north of the Panuco River, and on the San Antonio River west of Cruz there are hills composed of shales which lie nearly horizontally, while the underlying shales have a strong dip northwest. These shales closely resemble the Chicontepec in composition, and Cummins considers them of that age.

Near Padillo, which is at the junction of the Purificacion and Pilon rivers, east of Victoria, similar sandy shales were observed, and these may possibly be Chicontepec also. It is not thought probable that any of the shales west of El Abra Mountains are later than Papagallos, but, from Las Palmas eastward to Mendez, part or all of the shales are probably Chicontepec, and this condition continues southward.

Chicontepec

The Chicontepec beds are best seen in the extreme western portion of the Embayment area south of Aquismon, and especially in the hills lying just east of the great Cretaceous escarpment.

In places they are strongly folded as in the Chicontepec Mountain and almost everywhere show much stronger dips than the overlying Oligocene.

The Chicontepec beds proper seem to have been folded and eroded prior to the deposition of the Alazan shales.

From a locality in the Aquismon district, some 25 miles south of Valles, Jeffreys describes the following deposits, which he names the Tanlajas formation.

The Tanlajas series, as a whole, averages probably about 1100 feet in thickness. It consists, in the main, of marine deposits of rapidly alternating sandy limestones and shales. The base is composed of 250 feet of alternating beds of thin, sandy limestones, calcareous sandstones, and gray shales. The upper portion of these beds has one or two beds of calcareous blue sandstone, weathering to dark brown, which average, in places,

three feet thick. Some of the sandy beds have a strong petroleum odor while tarry black residues are frequent along fractures and fault planes. This residuum is of a brittle texture and disintegrates on burning. In other places it will take the slickenside markings of the surrounding walls, thus assuming an extreme similarity to lignite.

Overlying this there is a long stretch of coarse limestones about 450 feet thick. This limestone is brown in color, is fossiliferous in places, showing *Nummulites,* sp. *Turritella,* sp. and *Cardium,* sp. It also contains some sandy beds and carries small pebbles of rounded black chert and sandstone.

Overlying this we have another series of alternating calcareous sandstones and shales which carries some conglomerates locally. The harder beds in this series seem to have a predominance of ripple marks.

Jeffreys states that the Tanlajas formation follows southward from this point, along the front of the Tamasopa limestone outcrop, through the State of San Luis Potosi into Veracruz and Hidalgo. He says nothing whatever of its relation to the San Juan (San Felipe) or Papagallos (Mendez) and, as he was fully familiar with those formations a few miles to the north, it can be taken for granted that he considered this entirely different and later. While Jeffreys refers this to the Oligocene, it is probably the northward extension of the Eocene beds existing in like relation to the Tamasopa farther southward. Cummins considers it of similar age to the Chicontepec beds west of El Xuchil.

Apparently, these beds become more arenaceous as we go south from Tanlajas and San Pedro, and the limestones disappear. The most of the beds reported are marls overlain by flaggy sandstones and bluish shales with few fossils except nummulites.

Sixty-five miles southeast of Aquismon, and some fifty miles west of Tuxpam, Cummins and Sands found a series of beds, the lowest members of which were seen at the crest of an anticlinal ridge on Chicontepec Mountain, a mile and a half east of the town of Chicontepec, at an elevation of about 3,200 feet. The beds are composed of yellowish brown sandstones, some being two feet in thickness and containing weather-worn boulders, inclusions, or segregations of a very hard steel gray sandstone. The boulders seemed to carry some carbonaceous mat-

ter and lignitic matter was found in the cleavage planes of the sandstones. No leaves or fossils of any kind were found.

While the sandstones greatly predominate at the base they are interbedded with yellow clays and the sands become thinner and the clay bands become thicker higher in the section. Halfway down the mountain the sandstones carry boulders of concretionary clay ironstone, some of which are as much as two feet in diameter. Succeeding these beds the clays gradually give way to shales and the lower portion of the mountain was composed of bluish gray shale interstratified with fine-grained yellowish brown sandstone in layers three to six inches in thickness, while the shale beds are as much as a foot thick.

As there was no Tamasopa limestone observed in the area where we found the Chicontepec beds the relation of the two was undetermined.

From the strong resemblance of the Chicontepec beds to those of the Eocene at Ramones, Professor Cummins was inclined to refer them to that horizon.

It will be noted that while the upper beds are very largely made up of blue shales the basal beds, instead of being limestone like the San Juan, are sandstones.

The same shales and sandstones are well exposed in the hills south of El Xuchil, and numerous seepages of chapapote occur in these blue shales in the vicinity of the basaltic dikes which cut them at many places. Carmelita Ranch lies five miles north of El Xuchil, and a mile to the eastward the bed of an arroyo shows a dike of basaltic material coming up through blue shales which have been hardened on both sides of the basalt. The shale has been impregnated by asphalt, and, away from the dike, carries masses of clay ironstone in banded nodules. At Pedernalis Ranch, which is northwest of Carmelita, a similar bed of asphaltic shale was found, and the surrounding hills were made up of gray and blue shales. At one place the shales showed several thin bands of hard sandstones with fucoid-like impressions.

The beds, described by De Golyer as succeeding the Tamasopa southwest of Tuxpam and to which he applies the name of San Felipe Beds, apparently differ considerably from the San Juan (San Felipe of Jeffreys and Huntley) of the Valles region. He says of them:

"Overlying the Tamasopa limestone and resting unconformably (?) upon it is a series of alternating impure thin-bedded limestones and gray, red, and green shales and marls . . . . . The entire formation is somewhat sandy and contains locally beds of tuff of variegated colors which contain decomposed mica and are finely porous . . . . . With the exception of one or two doubtful inliers the outcrop of the formation is confined to a narrow strip adjoining the outcrop of the Tamasopa limestone in the mountain front. The thickness of the formation varies from 600 to 1000 feet . . . . . The formation . . . . . is apparently Tertiary if one may judge from the few fossils which have been secured from drill cuttings. If such is true it is of lower Eocene age. The formation grades imperceptibly into the overlying shales series, the limestones becoming gradually more argillaceous and impure and grading finally into hard shale and in turn into soft shale."

His description of his Mendez follows:[14]

"Grading from the underlying San Felipe beds is a thick series of gray to green shales, marls and clays containing rarely thin shaly sandstones and limestones and red shales . . . . ."

"This formation outcrops, for the most part, over the entire floor of the Sabanita basin. It is the surface rock of the Furbero field proper, extending from the Oligocene hills on the east to the lava flows at the foot of the hills of the Sierra Madre on the west. The thickness of this formation at Furbero is approximately 4000 feet. No fossils have been found in this region."

"Both the altered and unaltered shales of the Mendez formation, a series of blue and gray, medium soft, fine-grained shales, more or less calcareous in places, and (when not metamorphosed) a fairly constant lithological character throughout."

The Sabanita Valley, from which De Golyer describes his Mendez and San Felipe, is 60 miles southeast of Chicontepec. Aquismon is 65 miles northwest of Chicontepec.

At Aquismon the blue shales and clays, with "practically no change in their lithological character from top to bottom", gradually pass downward into limestone interbedded with similar blue shale.

[14] Trans. A. I. M. E. LII, p. 275.

At El Xuchil the blue and brown clays and shales are interbedded with brown sandstones, carry clay ironstone nodules in places, and gradually pass downward into sandstone.

At Sabanita the upper beds are gray to green shales, marls and clays with shaly sandstones and limestones grading downward into impure thin-bedded limestones interbedded with similar shales and with beds of tuff of variegated colors.

The materials of De Golyer's San Felipe, however, are apparently unconformable on the Tamasopa, and are very different from those found in the San Juan farther north, and if, as he suggests, such fossils as it contains are of Eocene age, his San Felipe can not possibly be correlated with the San Juan, which is undoubtedly Cretaceous. Furthermore, his overlying Mendez differs materially from that north of the Panuco River, and agrees more nearly with the upper portion of the Chicontepec beds of which we believe it to be the southern extension.

Similar shales appear in many of the exposures examined between the Panuco and Tuxpam rivers.

On the Tlacalula Ranch, northeast of El Xuchil, there are many exposures of beds similar to those between Chicontepec and El Xuchil. In many places the shales are standing at high angles and are cut by basalt dikes and frequently are impregnated with asphalt. They are blue to gray in color, interbedded with brown sandstones, and occasionally have bands of clay ironstone.

These are found in the beds of such creeks as Puente, Palma, and Coyote, and near the river Tamozus.

They are also found in the base of Mount Santo Domingo and between it and Cerro Tultepec. To the eastward they are found around Horcones and on the Buena Vista River at Alazan. Jeffreys reports them as underlying his Oligocene section at Temapache, six miles southeast of Alazan.

Southeast of Tamiahua, on the San Marcos River, Sands found good exposures of them and furnishes the following description:

"The beds are composed of bands of very hard light blue-gray, fine-grained calcareous shale which in places becomes almost a shaly limestone and varying in thickness from two inches to a foot, interbedded with softer bands of thicknesses varying from a few inches to fifteen feet. Some of these softer

bands are fine-grained clay shale, dark blue gray to red in color, and seeming to carry little or no sand in its composition. Others, on the contrary, are very sandy, and in some places, grade into a shaly sandstone with calcareous cement. No fossils were found here."

These shales occur here in gently undulating beds with prevailing dips of one to four degrees a little west of south.

These are apparently very similar to the shales called Mendez by De Golyer.

Blue shales were also observed on the Tuxpam River, west of Tumbadero, and near the coast as far south as the Arroyo Hondo, between Tecolutla and Nautla, and at many other localities in this region.

Just how far south these Chicontepec beds extend cannot be told at present, but they probably skirt the foot of the Cordilleras as far south as Nautla.

Böse does not appear to have recognized any beds referable to them in his Orizaba section.

In Chiapas, however, he finds similar beds, and states that the fossiliferous Eocene there consists of sandy shales, sandstones, clay shales, calcareous shales and limestones. The prevailing colors are red and yellow, although sandstones, shales, and limestones are occasionally gray or blue.

The Eocene fauna of this region, like that of the Chicontepec beds, appears to be almost altogether foraminifera—nummulites and orbitoides. The nummulites are found scattered over a considerable area, but the orbitoides were only found in a few localities. Dr. Paul Oppenheim, of Berlin, identified them as *Orbitoides orthofragmina,* a typical Eocene form.

Therefore, so far as our present observations go, Lower and Middle Eocene deposits such as occur in the Texas Gulf Coast region are not found on the Mexican coastal region south of the old barrier now represented by the Tamaulipas Range. Such deposits as do occur in the Mexican region, and which may represent the time equivalents of these Texas beds, are characterized by an entirely different fauna.

The succeeding Eocene beds as seen at Alazan are, apparently, unconformable on the Chicontepec. The fauna is a commingling of species occurring in the Tejon formation of the Pacific Coast with those of the Upper Claiborne and Jackson, or Upper Eocene, of the Gulf region. It has only been recog-

nized at a few localities so far, but even these remnantal deposits are of great value as proof of the direct connection of the waters of the Pacific and Atlantic oceans during the final stages of the Middle Eocene and in the Upper Eocene.

A large number of wells have been drilled in the area between the Panuco and Tuxpam rivers and from such logs as are available, it appears that all the wells which have proved good producers are drilled into the Tamasopa limestone which is encountered at depths from 1700 to 2400 feet.

The identity of the Tamasopa is fully proved by fragments of the limestone which have been blown out of the wells, in some of which fragments the rudistes are clearly present.

The drilling also shows that the Tamasopa, throughout most of this area, is overlain by the San Juan beds, but the irregular thickness of the beds so referable, showing, in place of the 800 feet usually attributed to this formation in this area when undisturbed, only 70 to 150 feet in places and occasionally seeming to be missing entirely, indicates that the San Juan was subjected to strong erosion prior to the deposition of the overlying shales. Since there is no such unconformity between the Papagallos and San Juan anywhere as is found between the limestones and shales in this area, it is evident that these shales are not Papagallos and therefore whatever thickness of Papagallos may have originally overlain the San Juan in this region was entirely removed together with a large portion of the San Juan prior to the deposition of the shales now covering them.

It is probable that a part of this shale belongs to the Chicontepec, especially in the western portion of the area, but it is also certain that a large part of it belongs to the Alazan, since samples of the drillings are identical in physical character with the typical shales and at times carry fragments of lamellibranchs like those of the Alazan. It is also possible that some part of it may belong to the San Rafael.

Just what part belongs to the Chicontepec and what to the San Rafael is as yet undetermined.

It is probable that a careful microscopic study of the drillings of the materials overlying the San Juan in connection with similar study of Chicontepec, Alazan and San Rafael sediments would enable us to draw the line between the two formations as found in the wells with some exactness.

The thickness of the Chicontepec probably exceeds 2,000 feet. De Golyer[15] cites fossils from the Tamijuin well from depth of 3150 feet which are said by Hopkins and Belt to have a decided Tertiary aspect and fossils from 2900 feet in Ganahl Well No. 1 at junction of Moctezuma and Tamuin rivers which were pronounced Tertiary by Dr. Hart. While the fossils are not named it is known that nummulites occur in the blue gray marls on the Tempoal River, as in other places in the Chicontepec, and it is, therefore, probable that the shales penetrated in these two wells are Tertiary, as stated,—but they are not Papagallos.

It has been suggested that in this region these Tertiary beds occupy a deep synclinal, none of the wells having reached the Cretaceous beds which are found so much nearer the surface to the east and west.

Alazan

Whether the fossiliferous shales at Alazan are an integral part of the lower hard blue shales or are unconformable upon them, has not yet been fully determined, but they are probably later and are certainly Upper Eocene.

The type locality of the Alazan shales is on the Buena Vista River at the crossing of the road between Alazan and Moyutlan.

At this place the stream has cut down to the blue shales and exposed that formation along its western bank and in the bed of the river for a distance of more than half a mile. Overlying the shales to the west is a hill of yellowish clay, probably Oligocene. On the east side of the river there is a broad valley covered to a depth of 20 feet or more with recent deposits.

The general body of blue shale seems to have been but little disturbed; for the most part it is smooth and evenly bedded and has a low dip to the southeast. Three hundred yards below the crossing there is a limited area which shows the surface of the shale more or less disturbed and broken, and it is here that the fossils occur. In places it appears as if small basins or potholes 8 to 10 feet in diameter had been eroded in the underlying shale and the fossil-bearing blue clays laid down in them. At other places the fossiliferous beds seem broken and piled together in every direction. The entire fossil-bearing area is not more than 200 feet in length and a few hundred yards below this the main

[15] Trans. A. I. M. E. LII, p. 266.

body of shales ends abruptly as though faulted and the water plunges into a deep pool.

The material in which the fossils occurs is very similar to that of the main body of the shales, but the fossils here are entirely confined to the disturbed and eroded area and not a single fossil was found elsewhere in this exposure and none at all was found in the main body of shale.

The fossils are fragile and while abundant in this limited locality are hard to separate from the shale.

A mile west of this locality on the Horcones road a small stream with high banks affords another exposure of the fossiliferous Alazan shales. These shales are evenly bedded and have not been folded or broken as at the first locality. They are immediately overlain by recent material so that relations were not seen. The material here is a bluish shale which weathers white, differing in appearance from the great body of shale to the north which belongs to the Cretaceous and resembling very closely beds found at Tlacolula Ranch, 18 to 20 miles west of this locality on the Arroyo Puente.

The fossils from the Alazan shales were submitted to Dr. R. E. Dickerson, who reports that they are of Upper Eocene age, containing some forms characteristic of the Tejon of California and others of the Upper Eocene of the Gulf Coast.

The following forms have been identified from these beds:

Orbitoides, sp.
Cristellaria, sp.
Corbula, sp.
Nucula (Acila), sp.
Nucula monrœnsis Aldrich
Chione, sp.
Pecten promens De Gregorio
" (Pseudamusium) calvatus Morton
" sp.
Tellina cf. subtriangularis Aldrich
Glycimeris, sp.
Mactra ?, sp.
Spisula, sp.
Dentalium, sp.
" stramineum Gabb
Cadulus subcoartatus Gabb

Conus remondii Gabb
" sauridens Conrad
" alveatus Conrad
" sp.
Cylichna, sp.
Epitonium, sp.
Drillia, sp.
" sp.
Eulima lugubris Lea
" sp.
Haminea, sp.
Galeodea, sp.
Lunatia, sp.
Mitra, sp.
Murex migus De Gregorio
Neverita cf. secta Gabb
Nyctilochus, sp.
Natica, sp.
Olivella near mathewsonii Gabb
Ringicula biplicata (Lea)
Sinum, sp.
Sinum striatum (Lea)
Surcula, new sp.
" sp.
Tritonium, sp.
Turritella cf. caelutura Conrad
Turris childreni (Lea)
" nupera (Conrad)
" acutirostra (Conrad)
" cf. suturalis Cooper
" cf. monolifera Cooper (Lea ?)
" sp.
" cf. mediavia equiseta Harris
Cerithium, sp.
Schizaster, sp.

The cuts of the Tampico and Panuco Valley Railroad in the vicinity of the Topila Hills show the Alazan marls underlying sandstones belonging to the San Rafael beds. If the Meson stage is present it has not been recognized. The Alazan marls at this locality carry fragments of a Schizaster and a few small

lamellibranchs. Similar marls with apparently the same Schizaster are found at Los Naranjos, Tempoal, Zacamixtle and elsewhere, proving in some measure the extent of the Alazan beds in this region.

Taken altogether, therefore, it would now appear that the section south of Aquismon probably corresponds closely with that described by Böse from Chiapas and Tabasco, but is more extended. The Tamasopa limestone, with occasional remnants of San Juan and Papagallos, is followed by Eocene deposits characterized by nummulites, orbitoides, etc., succeeded by Upper Eocene (Jackson) and this by Lower and Upper Oligocene.

OLIGOCENE

After the deposition of the Eocene sediments they were elevated and folded and, in this area, were base-levelled so that at the present time they form a comparatively level floor, the general surface of which is not far below the water-level of the region.

Upon this floor of Eocene sediments are found those of the Oligocene, which includes the greater part of the materials forming the various mountains, hills, and mesas of the region as well as those portions of the intervening valleys in which erosion has not reached the underlying Eocene. In many places they are penetrated by dikes and necks of basalt, and, at others, are covered by basalt flows. Some sedimentary deposits of Quaternary age also occur overlying them.

The Oligocene deposits consist of sands and sandstones, clays, marls, shales, with more or less calcareous matter, and limestone. These, where unaltered, are brown, gray, or blue, but are usually weathered yellow, which is their prevailing color throughout the region. By far the greater part of the beds are clays with more or less sand, the shales and limestones being most abundant in the middle portion of the beds.

These deposits were first studied by us on the lower Conchos River near the town of San Fernando, and that name was used to designate them[16]. Finding that the name was already in use the name San Rafael was adopted as a substitute[17].

[16] Tertiary Deposits of Northeastern Mexico, E. T. Dumble. Science, No. 841, pp. 232-4. 1911.
Tertiary Deposits of Eastern Mexico, E. T. Dumble. Science, No. 910, pp. 901-8. 1912.
[17] A Medial Tertiary Fauna from Northeastern Mexico. Proc. Cal. Acad. Sci. 1917.

On the Conchos River and along the eastern face of the Pomeranes Mountains to the north of that stream the only beds recognized were those belonging to the uppermost part of the formation. To the southward in the Martines and San Jose de las Rusias ranges to the vicinity of Tordo Bay lower beds than those of the Conchos predominate. South of the Tamaulipas Range in the Panuco River drainage area a considerable part of the fossil-bearing deposits seem to be of this same age, while south of the Otontopec divide we find, in connection with these deposits toward the coast, a considerable development of later beds similar to those on the Conchos.

The San Rafael, as here described, includes both the Eogene and Neogene of Villarello's report. Of the former, he says:

"The Sierra San Jose de las Rusias is made up of yellowish colored nummulitic calcareous rocks which belong to the Eogene and which extend to the north as far as the vicinity of Santa Maria de las Ovejas. To the west they extend to the plain of San Jose. To the east they pass under the Quaternary and Recent formations of the Coast, and south they reach as far as the same Sierra of San Jose . . . . . These beds belong to the Eogene and form slight folds; sometimes cross-folding. The general structure is monoclinal." (P. 12.)

The overlying beds, or "Neogene," are made up in this vicinity of argillaceous shales, while around Ebano the beds he correlates with these are thus described:

"The Tertiary of this region is made up of yellow clay shales and blue or bluish gray marls. Interpolated in these marls and shales are sandstones with a clay and sometimes calcareous cementing material. These rocks outcrop chiefly, although to a very small extent, toward the west from Ebano and some portions of the plain where generally they are covered by the Quaternary and Recent formations of the Gulf Coast."

Jeffreys' section of the Tampico Tertiaries shows at the base semi-crystalline fossiliferous limestone with some shales, also a coarse crystalline limestone and the blue calcareous sandy marl. This is overlain by a soft calcareous sandy material interbedded with white nodular forms. The succeeding beds consist of coarse limestone weathering to yellow and carrying oysters. The top bed is of sandy turritella limestone with calcareous sandstone beds containing white nodular forms.

Jeffreys, speaking of the Ozuluama and Temapache regions, says:

"These Tertiaries chiefly consist of coarse limestones, fossiliferous as at Ozuluama and Topila; there are also strata of bluish limestones weathering to yellow, and some soft coarse blue sandy silt deposits underlying the former; nummulites are present in most of the limestones, but more abundant in certain sections, especially near by Ozuluama. The so-called Temapache limestones are decidedly of a higher horizon than that of the Ozuluama Series, but are very similar in lithological character. They are somewhat thicker, however, and probably ostrea are more abundant in the southern series. There are also a few more or less localized conglomerates in the Tancochin area.

"The whole series throughout are interbedded with a softer calcareous yellow sandy material, full of small white calcareous forms.

"Under what conditions these Tertiaries were deposited is difficult to estimate, but they were probably laid down in not a very deep sea.

"The Tertiary beds on the eastern side, moreover, are not homogeneous throughout. That is to say, we have beds in the southeastern and central portion which are not represented with a similar bed at the same horizon in the northeastern section."

In the vicinity of Tuxpam we find shales, marls, and sandstones overlying fossiliferous yellow limestones. Similar beds are found southward along the Cazones River and eastward almost to the Gulf shore at Nautla.

De Golyer[18] says of the beds in this region:

"Overlying the Mendez shales is a thick series of sandstones, shales, impure fossiliferous limestones and occasional conglomerates of Oligocene age. The various strata making up this formation are lenticular and grade laterally into each other. Near the front of the Sierra Madre occur beds of shale so thick that their outcrops are hardly distinguishable from those of the Mendez shales."

[18] De Golyer, A. I. M. E., p. 1906.

The comparatively superficial character of these beds is well shown in the Topila district. Here the Topila Hills, several hundred feet high, seemingly show a section of more than 1000 feet of clays with interbedded sandstones and limestones carrying fossils of San Rafael age, and yet wells drilled along their western foot show none of them.

In places these beds are very fossiliferous and based on the fossil fauna they may be divided into three stages, although possibly the two lower may be ultimately combined into one. These, beginning with the lowest, will be called the Meson, San Rafael and Tuxpam stages.

Meson

The type locality of the Meson beds is in the valleys lying between Moralillo and Meson on the trail leading from Tamiahua to Alazan. These beds consist for the most part of yellow sandy clays with some lime and sandstone. It is characterized by the large foraminifer *Orbitoides papyraceæ,* Bou. These fossils occur here in great number, but they have not been observed higher in the series. These beds, with their characteristic fossils, are also found near San Jose in the San Jose de las Rusias region underlying the San Rafael.

San Rafael

The San Rafael, from which these beds are named, is located on Zarzizal Creek, 65 miles north of Tampico. Four miles east of the town a range of hills 300 to 400 feet high is composed of beds of yellow clay alternating with bands of clayey limestones[19]. The fossils are abundant and include corals, mollusca, echinoderms and foraminifera. The corals, echinoderms and forams are quite distinctive and through them the beds of this stage are easily distinguished for a considerable distance to the north and south of the type locality.

While considerable stress seems to be placed on the limestones of this division, they are not the predominant materials, which consist of gray, blue, and yellow clays, shales, and marls, with occasional beds of sandstone. The limestones are more or less local in their development.

[19] Tertiary Deposits of Northeastern Mexico, Cal. Ac. Sc. Vol. 5, No. 6, p. 189.

Beds of San Rafael age occur in the vicinity of Tampico, both to the west of the city and between the city and the Gulf.

Among the best exposures of these deposits in the region under discussion are those found in the Topila Hills, 15 miles southwest of Tampico, where there are many good exposures of beds of limestones with characteristic fossils. There are also numerous exposures to the south, although where the limestones and fossils are lacking the identity of the beds is not so easily determined.

Jeffreys, in describing his Temapache section, which seems to belong to this stage, states that succeeding what he calls the Mendez series, there is a dark bituminous sandstone containing sharks' teeth and nummulites, overlain by limestones and occasional conglomerate carrying ostrea, pectens, nummulites, and turritella. Above this comes a hard, coarse to fine-grained limestone, replaced upwards by a hard, coarse yellow limestone with calcareous sandstone, as in the Ozuluama beds, carrying turritella, ostrea, and pectens. The top of this section is the hard Temapache limestone. Still another section is given in the Cuchares River area which shows limestones and thin beds of shale overlain by calcareous sandstone, and this by Le Pena gray limestone with nummulites. Above this there are beds of semi-crystalline limestone, some of them being highly fossiliferous, while the top is formed of turritella limestone interbedded with yellow calcareous sandstones.

The fossils found in the San Rafael stage include the following:

Foraminifera:[20]

Orbitoides epphippium
Nummulites radiata ?

Corals:[21]

Orbicella cellulosa Duncan
Orbicella, n. sp.
Maeandrina, n. sp.
Acropora, sp.?
Favites ? polygonallis Duncan
Goniastrea antiguensis Duncan
Goniopora, sp. very similar to, or identical with, an Antiguian species.

[20] Determinations by R. M. Bagg.
[21] Determinations by T. Wayland Vaughan.

Echinoderms:[22]

Clypeaster concavus Cotteau
" sp. a Dickerson & Kew
" sp. b " " "
Eupatagus, sp. " " "
Lovenia dumblei Dickerson & Kew
Macropneustes mexicanum Dickerson & Kew
Schizaster scherzeri Gabb.

Mollusca:[23]

Ostrea, sp.
Pecten gatunensis Toula
" oxygonum-optimum B. & P.
Turritella altilira Conrad

Tuxpam

Following the clays, shales, and limestones of the San Rafael, we find another series of clays and shales which is also very fossiliferous in places as in the vicinity of Tuxpam, which place gives them their name.

The Tuxpam beds comprise yellow clays and sandy clays, blue sandy shales and bands of calcareous sandstone. For the most part, the beds seem to lie nearly flat and show little disturbance, even in the vicinity of volcanic necks.

They are well exposed around San Fernando, on the Conchos River, have not been definitely identified at Tampico, but form a large part of the surface material around Tuxpam and southward to Larios and Nautla. While the contact of the Tuxpam and San Rafael beds has not been positively observed, we may conclude that a decided unconformity exists because there are numerous small anticlinals to be seen in the San Rafael, while the Tuxpam beds seem to show little or no disturbance of this character. A further study will probably demonstrate that south of the Otontopec divide the Tuxpam beds overlap the San Rafael in many places, as they certainly do in the region north of Tordo Bay.

While certain molluscan forms seem to be common to the San Rafael and the Tuxpam, the number of species occurring in the Tuxpam is very much greater. The echinoderms of the

[22] Determinations by Dickerson & Kew.
[23] Determinations by Dickerson & Kew.

Tuxpam seem to be specifically distinct from those of the San Rafael, corals are much scarcer and there is no such number or variety of foraminifera as in the lower beds.

The following list of fossils of the Tuxpam stage is from the report of Dickerson & Kew:

Echinoderms:

Agassizia clevei Cotteau
Cidaris cf. loveni Cotteau
Clypeaster cubensis Cotteau
Macropneustes antillarum Cotteau
Metalia cumminsi Dickerson & Kew
Scutella cazonesensis Dickerson & Kew

Molluscs:

Astarte, sp.
Arca, sp.
Antigona glyptoconcha Dall
Cardium, sp.
" gatunense Toula
" lingua-leonis Guppy
Clementia cf. dariena Conrad
Chione cf. ballista Dall
Glycimeris, sp.
Meretrix, sp.
Mya, sp.
Macoma ? sp.
Ostrea haitiensis Sowerby
" trigonalis Conrad
" sp.
Paphia, sp.
Panope, sp.
Pecten gatunensis Toula
" cf. " "
" condylomatus Dall.
" levicostatus Toula
" sp.
Tellina
Architectonica, sp.
Amphissa, sp.
Conus interstinctus Guppy
" sp.

Cypraea, sp.
Ficus, sp.
Malea ringens Swainson
" sp.
Melongena, sp.
Natica, sp.
Olivella, sp.
Sinum, sp.
Turritella, sp.
Urosalpinx, sp.
Xenophora, sp.

Böse states that the Semijoval division which overlies the Eocene deposits in Chiapas may possibly include both Oligocene and Miocene deposits. This division consists of argillaceous shales, blue clays, gray sandstones, and limestones. The fauna, which was not carefully studied, embraced *ostrea,* sp.; *pecten,* sp.; *turritella,* sp.; *strombus,* sp.; *conus planiceps, echinolampas,* sp.; *clypeaster* cf. *meridianus,* etc. in the shales, with some corals and pectens in the limestones. From this it would appear that there is seemingly a strong resemblance between the Semijoval and the San Rafael, just as there is between his Chiapas Eocene and the Chicontepec.

NEOCENE

North of the Tuxpam River sedimentary beds of later age than the Oligocene seem to be confined to those of late Pliocene or Pleistocene age.

In the northern portion of the Embayment area, lying between the Tamaulipas Range and the Cordilleras we find, resting directly on the Papagallos shales, beds of materials corresponding in every way to the Reynosa of Southwest Texas and Northeastern Mexico. It consists of conglomerates, gravels, and sands, with some clays and more or less calcareous cementing material, which, in many places, takes the form of caliche.

Similar beds are found east of the Tamaulipas Range and southward throughout the area.

East of the Tamaulipas Range we find overlying the Oligocene clays and sands, in a number of localities, a rather heavy

bed of broken shells, making a true coquina. In places this is found well up in the hills or forming the tops of hills. Just how it is related to the Reynosa is not known.

The Reynosa, as shown by its relations to fossiliferous beds above and below it, is Upper Pliocene and our idea is that the Coquina is of similar age.

Going southward we find, around Tampico and the Laguna Viejo, beds of sandy clay with *Ostrea virginica* and a few other shells of like recent affinities. Similar deposits occur in the area between Tampico and Tuxpam and to the south of the Tuxpam River.

All of these deposits are more or less local in their distribution, and have not been studied sufficiently to permit a fuller description.

While no fossiliferous beds of Miocene or earlier Pliocene age are known within the area here discussed, they do occur farther south and more detailed work may discover extensions of them in this region also.

The nearest locality at which such fossils have been collected and identified is Santa Maria Tatetla, Veracruz, about sixty miles south of Nautla. This was described by Böse in Bulletin 22 of the Mexican Geological Institute. Both Böse and Villarello state that a similar fauna is found in deposits occurring near Actopam and Tezuitlan which lie between Santa Maria Tatetla and Nautla.

The following is from Böse's description:

Santa Maria Tatetla is a native town in the Canton of Huatusco and 25 or 30 miles northwest of the city of Veracruz. It is situated in the bottom of a deep barranca at an elevation of 349 meters on the bank of the Rio Santa Maria, which, after uniting with several arroyos, forms the Rio Antigua and enters the gulf near Antigua. The general character of the region is that of an extended mesa almost perfectly flat, somewhat inclined towards the east and cut by numerous barrancas. Towards the north and west the mountain rises in sierritas made up chiefly of Middle Cretaceous limestones and modern eruptive rocks. The upper part of the mesa is mostly a conglomerate of eruptive rocks horizontally stratified and in all probability an upper Pliocene and Post-Pliocene Marine formation. Beneath these conglomerates there are outcrops of the Escamila

division of the Middle Cretaceous, one of these being to the south of Apasapan, and another near Santa Maria Tatetla, where there are limestone beds carrying *Rudistes, Actæonella, Nerinea,* etc. At Palmer the limestones carry *Caprina* and other Cretaceous fossils. On top of these come calcareous conglomerates, marls, and sands somewhat consolidated and sandstones carrying the fauna described as Pliocene. Above the fossiliferous beds come a conglomerate of modern eruptive rocks.

The Tertiary fossiliferous bed occurs at an altitude of 280 meters above the sea-level, and, in the bottom of the barranca, about four kilometers below Santa Maria. The bed extends eastward and the same fossils are found in a somewhat harder limestone at an elevation of 150 meters at Puente Nacional. That the beds dip to the east may be seen from the altitude of the fossil localities.

The sandstones and sand in the Barranca Santa Maria admit of two divisions: *Ostrea, Ammussium* and *Encope* are the more abundant in the lower division and in the upper there are numerous bivalves of other genera and gasteropods, but, with the exception of *Ammussium,* the species are rather scarce. Both divisions carry many forms in common and are undoubtedly of the same age.

The fauna found in this region comprises the following:

Encope Tatetlænsis, n. sp. (frequent)
Pecten Aztecus, n. sp.
" santarosanus Böse
Ammussium mortoni Rav. (frequent)
Pinna serrata Sow. (frequent)
Anomia simplex D'Orb.
Ostrea virginica Gmelin (frequent)
" sculpturata Conr.
Arca taeniata Dall.
Lucina quadrisulcata D'Orb.
" pectinata Gmelin
Laevicardium sublineatum Conr. (frequent)
" serratum Linnæus (frequent)
Dosinia elegans Conr. (frequent)
" acetabulum Conr. (frequent)
Venus ebergenyii Böse (frequent)

Solecurtus cummingianus Dunk.
" gibbus Spengl.
Semele perlamellosa Heilpr.
Panopaea floridana Heilpr.
Xenophora conchyliophora Born.
Sigaretus cfr. multiplicatus Dall.
Turritella Aguilerae Böse.
Cerithium caloosaense Dall.
Strombus pugilis Linnæus (frequent)
Pyrula papyratia Say (frequent)
Dolium cfr. galea Linnæus
Oliva litterata Lam. (frequent)
Balanus eburneus Gould.

Nearly all the fossils occur in the form of casts and it is not possible to determine a number of the species on account of the absence of ornamentation or because, being new species, they cannot be determined for want of better preserved material.

This fauna appears to be a littoral or at least comparatively shallow water one and many of the species or their kindred are still living in the adjacent sea. The Santa Maria Tatetla, Santa Rosa, and Tuxtepec species appear to belong to the same fauna and same age, which, although given as Pliocene, in the publication quoted, is now regarded (so Böse says) on account of larger and more complete collections, as Miocene.

Igneous Rocks

The igneous rocks occurring in this area are nearly all basaltic.

They occur as dikes of various widths, as plugs or bosses, and in beds forming the tops of hills and mesas.

The great number and extent of the dikes suggest that the lavas which form the caps of the hills and mesas came up as sheet flows rather than through craters.

Huntley[24] gives two maps showing the location of a number of these dikes running in different directions, together with surface flows and states that the peaks and plugs of basalt are usually found at the intersection of such dikes.

[24] Trans. A. I. M. E. LII, pp. 302, 310.

Garfias[25] has described the mushrooming of these plugs in sending out sills of basalt through the bedded limestones.

De Golyer[26] expresses the opinion that the lava cap was originally continuous over a very large part of the area, and that the flow occurred after the deposition and folding of the entire series of marine sediments.

The largest single body now remaining in this area is probably that of the Otontopec Range or Mesa, but there are many other detached mesas and hills which still show their lava covering resting upon the yellow, sandy clays of the Oligocene.

History

The movement, which, during the later portion of the Austin Chalk period, caused the formation of the Sabinas barrier in northern Mexico, was probably the beginning or directly connected with the one that began the deformation which has resulted in the present conditions of our area.

East of the Sabinas barrier the Taylor, with its coal beds and the overlying Escondido, were laid down with little, if any, interruption, and are followed by the basal Eocene without any evidence of an erosion interval between.

One hundred and sixty miles south, at Ramones, on the Salinas River, where we found the contact of the Papagallos (which represents the Taylor, in some part, at least), and the same basal Eocene, we see that the Papagallos has been strongly folded and eroded prior to the beginning of Eocene deposition. Similar folding is evident in the San Felipe-Valles region.

The initial movement in this area was, therefore, immediately following the deposition of the Papagallos and the fact that between the Panuco and Tuxpam rivers not only the entire thickness of Papagallos, but, in places, that of the San Juan was removed prior to the submergence which permitted the beginning of the deposition of the Eocene, indicates that the erosion was very active. Farther south it was even more active as the Rudistes limestone also seems to have been carried away.

The Midway or basal fauna of the Gulf Coast Eocene is found as far south as the Tamaulipas Range but has not been

[25] Journal of Geology, Vol. XX, No. 7, p. 666.
[26] Trans. A. I. M. E. LII, p. 275.

observed again north of Venezuela, 2,000 miles away. Fossils of the Lower Claiborne occur along the Conchos River not more than 30 or 35 miles from the upper end of the Embayment area, near Linares, but are not known farther south.

The waters of the Eocene sea covering the Tampico Embayment area probably came in from the south and were either entirely separated from those of the Gulf or their connection was such that the faunas did not mingle.

Toward the close of the Middle Eocene further elevation and folding took place. This is shown in the Pomeranes Mountains north of the Conchos River, in the mountains east of Burgos, south of that stream, at Alazan, and at Chicontepec. This movement is also evidenced on the Texas coast by the absence of the Upper Claiborne and the erosion of a part of the Lower Claiborne prior to the deposition of the Upper Eocene or Jackson.

The succeeding submergence clearly shows a connection in the Embayment area of the waters of the Pacific and those of the Atlantic by the commingling of the Pacific and Gulf types of fossils at Alazan where Tejon forms of the west are mingled with Jackson and possible Upper Claiborne forms from the Gulf.

The close of the Eocene was marked by further folding, elevation, and erosion.

The Oligocene submergence, which followed, seems to have affected not only the entire Gulf region, but the Carribean as well, and since almost identical faunas are reported from the west coast of Mexico, it is probable that the passage between the Oceans was still open.

With the final emergence of the Oligocene* important sedimentation in our area seems to have ceased, and was succeeded, probably during the Miocene, but, seemingly, before any great erosion had taken place, by the vulcanism which gave us the dikes, necks, and caps of basalt.

To the north and south of this area the coast was subjected to further submergence and deposits of Miocene and Pliocene age were laid down, but such Post-Oligocene submergences as may have occurred in this portion of the Tampico Embayment area seem to have been relatively unimportant.

* The nummulitic limestones of the San Rafael beds are ample warrant for their reference to the Oligocene. The Tuxpam beds were included in the Oligocene because of the identity of certain ferns. Some of these ferns, however, seem to indicate a later horizon and closer collecting may necessitate a reference of the Tuxpam beds to the Miocene.